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Enrichment of Flux by Nickel to Improve Impact Strength in Submerged Arc Welding

Er.Kuldeep Sharma
Mechanical Engineering Department, G.I.T.M. Bilaspur, Yamuna Nagar (Haryana), India
kuldeep981@gmail.com

Abstract:-The current work is an effort to study the effect of Nickel metal powder addition in flux, on the impact strength, of IS 2062 steel during submerged arc welding. The effect of types of flux (with and without nickel powder addition in AUTOMELT B31 flux) by keeping the welding parameters like welding voltage and welding speed constant has been evaluated. Taguchi technique has been used for the design of experiments. The effects of flux with or without nickel metal powder addition, voltage and travel speed have been evaluated on the impact strength. The effect of all the input parameters on the output response has been analyzed using the analysis of variance (ANOVA).

Keywords: SAW, impact strength, Taguchi technique, ANOVA.

1. INTRODUCTION

In submerged arc welding a granular weld flux layer protects the welding point from the influence of the surrounding atmosphere. Unused flux can be extracted from behind the welding head and subsequently recycled. The filler material is an uncoated, continuous wire electrode, applied to the joint together with a flow of grained flux, which is supplied from a flux hopper through a tube. The electrical resistance of the electrode should be as low as possible to facilitate welding at a high current, and so the welding current is supplied to the electrode through contacts very close to the arc and immediately above it. The current can be direct current with electrode positive (reverse polarity), with negative (straight polarity), or alternating current. The arc burns in a cavity which apart from the arc itself, is filled with gas and metal vapour. The size of the cavity in front of the arc is delineated by unmelted basic material and behind it by the molten weld. The top of the cavity is formed by molten flux.

In this experiment automatic submerged arc welding machine is used. In fully automatic welding, the flux is fed mechanically to the joint ahead of the arc, the wire is fed automatically to the welding head, the arc length is automatically controlled and the traverse of the arc or the work piece is also automatic.

R.S. Chandel, H.P. Seow and F.L. Cheong (1997) Research on Effect of increasing deposition rate on the bead geometry of submerged arc welds. A.M. Mercado, V.M. Hirata, and M. L. Munoz (2005) an investigation influence of the chemical composition of flux on the microstructure and tensile properties of submerged-arc welds. V.B. Trindade, R.S.T. Mello, J.C. Payão, and R.P.R. Paranhos (2005) explain the influence of Zirconium on Microstructure and Toughness of Low-Alloy Steel Weld Metals. P. Kanjilal, T.K. Pal and S.K. Majumdar (2006) expressed the combined effect of flux and welding parameters on chemical composition and mechanical properties of submerged arc weld metal. S Kumanan, J.E.R. Dhas and K Gowthaman (2007) determine the submerged arc welding process parameters using Taguchi method and Regression analysis. S Datta, A Bandyopadhyay and P.K. Pal using the Taguchi philosophy for parametric optimization of bead geometry and HAZ width in SAW using a mixture of fresh flux and fused flux. S Datta, A Bandyopadhyay and P.K. Pal (2008) using the Slag as a recycling process in submerged arc welding and its influence on weld quality leading to parametric optimization.

B. Beidokhti, A.H. Koukabi, and A. Dolati (2009) explain the effect of titanium addition on the microstructure and inclusion formation in submerged arc welded HSLA pipeline steel. R Kaushik and V.P.Aggarwal (2010) develop fluxes for submerged arc welding of high strength low alloy steel.

After literature study we find that very few efforts have been made to understand mechanical properties using Taguchi Technique and Very little work is made to improve the weld joint strength in single pass. In this experiment we added nickel metal powder in 10 % and 20 % concentration in AUTOMELT B31 flux and investigate its effect on impact strength. The optimization of result has been done by Taguchi's Philosophy.

2. EXPERIMENTAL DESIGN

The purpose was to estimate the effect of various process parameters on the impact strength in submerged arc welding.

CONTROL FACTORS

The control factor was selected on the basis of a pilot experiment by varying one factor at a time. Based on the pilot study, voltage, travel speed, and type of flux (with and without nickel powder addition in AUTOMELT B31 flux) were identified as the control factors. The current and electrical stick-out was kept constant during the study.

a. VOLTAGE

During the pilot experimentation it was observed that an increase in arc voltage the bead width also increases and bead height decrease. Based on the pilot experiment results, the voltage was also set at three levels namely (a) 26 Volt, (b) 30 Volt, and (c) 34 Volt.

b. TRAVEL SPEED

Variations in travel speed at a set current and voltage also affect bead shape. As welding speed is decreased, heat input per length of joint increases, and the penetration and bead width increase. The penetration will increase until molten metal begins to flow under the arc and interfere with heat flow at excessively slow speeds. Based on the pilot experiment results the travel speed was set at 10, 12, and 14 m/h.

c. TYPE OF FLUX

Three types of flux were used for the experimentation. Where 1st flux is (AUTOMELT B31), 2nd flux is (10 % Nickel powder addition in AUTOMELT B31) and 3rd flux is (20 % Nickel powder addition in AUTOMELT B31). The percentage compositions of AUTOMELT B31 flux are given in Table 1. Various levels for the input process parameters.

Table 1 Percent composition of the AUTOMELT B31 flux

Flux	SiO2+TiO2	CaO+MgO	Al2O3+MnO	CaF2
1.	15	20	30	35

3. EXPERIMENTAL SET-UP AND PROCEDURE

The experiments were conducted on a submerged arc welding machine (Make: ADOR Frontech Ltd, Model: Tornado SAW M-800) and FD 10-200T welding tractor available at PT-2 Lab of M. M. University (Mechanical Engineering Department), Mullana (Ambala). The set-up of the experimental study is shown in Fig. 1.

The work material used for present study is IS 2062 mild steel, the dimensions of each piece is 260×130×10mm. We have 18 plates of this dimension for 9 experiments. Work material IS 2062 (composition by weight: 0.1624% C, 0.9917% Mn, 0.1095% Si, 0.01426% P, 0.00752% S, balance Fe) and wire electrode EH-14 (composition by weight 0.14% C, 1.20% Mn, 0.10% Si, 0.002% Ti, 0.007% Nb, 0.002% V, 0.03% S, 0.02% P, balance Fe) were used during the experiment.

Fig. 1 SAW set-up used for experimentation

Taguchi's philosophy is an efficient tool for the design of high quality manufacturing systems. Dr. Genichi Taguchi, a Japanese quality management consultant, has developed a method based on orthogonal array experiments in 1980.

The first step in the Taguchi method is to determine the quality characteristic to be optimized. The quality characteristic is a parameter whose variation has a critical effect on product quality. It is the output or the response variable to be observed. Examples are weight, cost, corrosion, target thickness, Hardness, strength of a structure, and electromagnetic radiation. There are three types of quality characteristics in the Taguchi methodology, such a Smaller-the-better, Larger the- better, and Nominal-the-best. For example, smaller-the-better is considered when measuring fuel consumption of an automobile or shrinkage of a plastic component. Experimental quality characteristics are shown in Table 4. Before selecting a particular OA to be used as a matrix for conducting the experiments, the following two points were first considered: (1) the number of parameters and interactions of interest. (2) The numbers of levels of the parameter of interest.

The non-linear behavior, if exists, among the process parameters can only be studied if more than two levels of the parameters are used. Therefore, each parameter was analyzed at three levels. The selected numbers of the process parameters and their levels are shown in Table 2.

For the sake of simplification, the second order interaction among the parameters is not considered. Each three level parameter has 2 degree of freedom (DOF) (Number of level – 1), the total DOF required for three parameters each at three levels is 8[4x (3-1)]. As per Taguchi's method the total DOF of the OA must be greater than or equal to the total DOF required for the experimentation. So an L_9 OA (a standard 3- level OA) having 8(9-1) degree of freedom was selected for the present analysis. The standardized Taguchi-based experimental design used in this study was an L_9 orthogonal array, as described shown in Table 3.

This basic design uses up to three control factors, each with three levels. A total of nine runs must be carried out, using the combination of levels for each control factor. The addition of noise factors is optional, and requires each run to be conducted once for each combination of noise factor. The selected parameters are shown in Table 2

Table 2 Factors studied with their levels

Factors (unit)	Notation	Levels Level 1	 Level 2	 Level 3
Voltage (Volt)	A	26	30	34
Travel speed (m/h)	B	10	12	14
Type of flux	C	AUTOMELT B31flux	10 % Nickel powder addition in AUTOMELT B31 flux	20 % Nickel powder addition in AUTOMELT

Table 3 L_9 design table with trial conditions

Tria No.	Voltage (Volt)	Travel speed (m/h)	Travel speed (m/h)
1	26	10	1
2	26	12	2
3	26	14	3
4	30	10	2
5	30	12	3
6	30	14	1
7	34	10	3
8	34	12	1
9	34	14	2

The S/N ratio developed by Dr. Taguchi is a performance measure to select control levels that best cope with noise. The S/N ratio takes both the mean and the variability into account. The S/N ratio is the ratio of the mean (signal) to the standard deviation (noise). The ratio depends on the quality characteristics of the product/process to be optimized. The standard S/N ratios generally used are as follows: nominal-is-best (NB), lower-the-better (LB), and higher-the-better (HB). (S Datta, A Bandyopadhyay and P.K. Pal (2007)) The S/N ratio for LB, NB and HB can be calculated by:

- Larger is better:

$$\left(S/N\right)_{HB} = -10 \log\left(MSD_{HB}\right) \quad \text{Where} \quad MSD_{HB} = \frac{1}{R}\sum_{j=1}^{R}\left(1/y_j^2\right)$$

- Nominal is best:

$$\left(S/N\right)_{NB} = 10\log 10\ (MSD_{NB})$$ Where

$$MSD_{NB} = \frac{1}{R}\sum_{j=1}^{R}(y_j - y_o)^2$$

- Lower is better: $\left(S/N\right)_{LB} = -10\ \log(MSD_{LB})$ Where $MSD_{LB} = \frac{1}{R}\sum_{j=1}^{R}(y_j^2)$

The plates after welding are shown in Fig. 2.
For this experimental work, the following response characteristics have been studied.

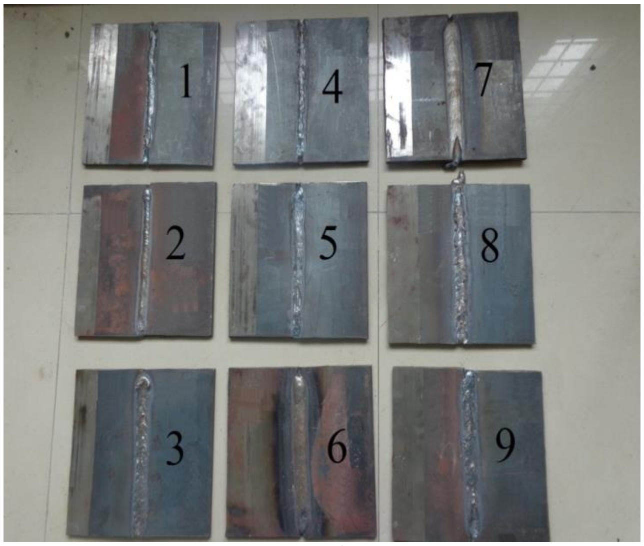

Fig. 2 Plates after welding.

Table 4 study of following response characteristics

Responses	S/N ratio
Impact strength	Larger is better

4. IMPACT TEST AND ITS RESULT

The testing would be carried out on impact testing machine available at Ganpati Institute of Technology and Management (mechanical engineering department), Bilaspur (Yamuna Nagar) at room temperature. Table.5 shows the result of Impact strength and it's mean.

Table 5 Results for Impact strength

Trial no.	Voltage (v)	Travel speed (m/h)	Flux	y.s 1 (j)	y.s 2 (j)	y.s 3 (j)	y.s 4 (j)	mean (j)	s/n ratio
1	26	10	1	156	150	164	170	160.00	44.0528
2	26	12	2	223	218	223	217	220.25	46.8563
3	26	14	3	258	262	255	250	256.25	48.1695
4	30	10	2	194	192	208	206	200.00	46.0043
5	30	12	3	266	260	268	275	267.25	48.5331
6	30	14	1	184	180	179	186	182.25	45.2101
7	34	10	3	287	290	283	280	285.00	49.0946
8	34	12	1	208	213	206	216	210.75	46.4708
9	34	14	2	244	240	246	239	242.25	47.6835

In case of more than single reading s/n ratio and mean is calculated. ANOVA has been performed in the statistical software package MINITAB 15. The analysis of variance is carried out at 95% confidence level. The main purpose of analysis of variance is to investigate the influence of the design parameters on Impact strength by indicating that which parameters is significantly affected the quality characteristics. In our experimentation work, we have generated results for S/N ratio of Impact Strength.
Test pieces after impact test is shown in Fig. 3.

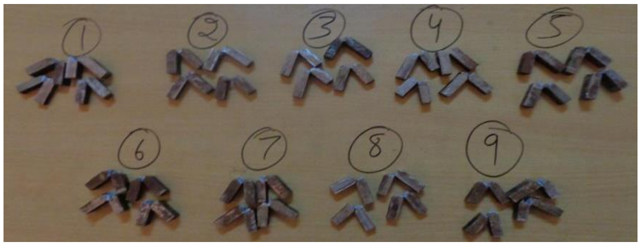

Fig. 3 Test pieces after impact test

Table 6 Analysis of variance for S/N ratio of Impact Strength

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Voltage	2	3.3441	3.3441	1.67207	25.03	0.038
Travel Speed	2	1.2916	1.2916	0.64580	9.67	0.094
Flux	2	16.8897	16.8897	8.44485	126.43	0.008
Residual Error	2	0.1336	0.1336	0.06679		
Total	8	21.6590				

Response table for S/N ratio of Impact Strength is shown in Table 7. The response tables show the average of each response characteristic for each level of each factor. The tables include ranks based on Delta statistics, which compare the relative magnitude of effects.

Table 7 Response table for S/N ratio of Impact Strength

Level	Voltage	Travel Speed	Flux
1	46.36	46.38	45.24
2	46.58	47.29	46.85
3	47.75	47.02	48.60
Delta	1.39	0.90	3.35
Rank	2	3	1

Main Effect Plot for s/n ratio of Impact Test also generated by this software is shown in Fig. 4.

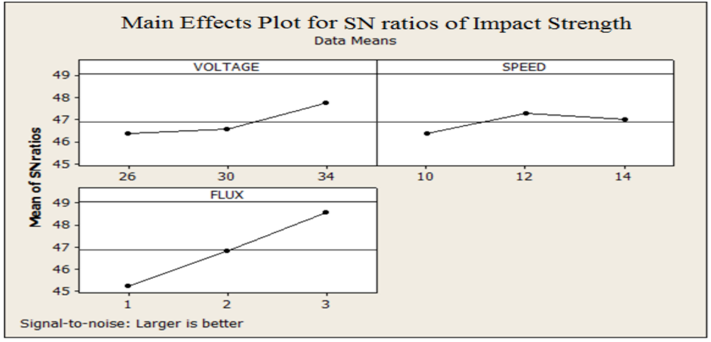

Fig. 4 Main Effect Plot for S/N ratio of Impact Strength

Table 8 Analysis of variance for mean of Impact Strength

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Voltage	2	2033.7	2033.7	1016.86	24.39	0.039
Travel Speed	2	491.1	491.1	245.55	5.89	0.145
Flux	2	10954.1	10954.1	5477.03	131.36	0.008
Residual Erro	2	83.4	83.4	41.69		
Total	8	13562.3				

From Table 8 we can conclude that flux and voltage is significantly affects the Impact strength and travel speed is insignificantly affects the Impact strength. Response table for mean of Impact Strength is shown in Table 9. The response tables show the average of each response characteristic for each level of each factor. The tables include ranks based on Delta statistics, which compare the relative magnitude of effects.

Table 9 Response table for mean of Impact Strength

Level	Voltage	Travel Speed	Flux
1	212.2	215.0	184.3
2	216.5	232.8	220.8
3	246.0	226.9	269.5
Delta	33.8	17.8	85.2
Rank	2	3	1

Main Effect Plot for mean of Impact Test also generated by this software is shown in Fig. 5

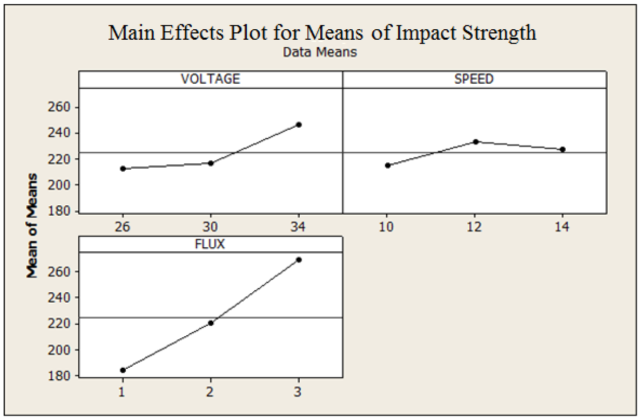

Fig. 5 Main Effect Plot for mean of Impact Strength

Table 10 shows that the Optimum combinations of Parameters.

Table 10 Optimum combinations of Parameters

VOLTAGE	TRAVEL SPEED	FLUX
Level 3	Level 2	Level 3
34 V	12 m\h	3

So, on the basis of main effect plot we can say that Impact Strength of mild steel of grade IS 2062 will be the Maximum when we using voltage 34 V, travel speed 12 m\h and flux 3. So these are optimum welding parameters on which we can attain the higher Impact strength of IS 2062 mild steel welds.

5. CONFORMATION TEST

When the optimal level of design parameters has been found, then the final step is to predict and verify the improvement of the quality characteristic using the optimal level of design parameters. So, on the basis of Table 10 conformation test has been carried out. Table 11 shows the result of conformation test.

Table 11 Result of conformation test.

Voltage	Travel Speed	Flux	TENSILE STRENGT (MPa)
34	12	3	295

6. CONCLUSION

Taguchi optimization method was applied to find the optimal process parameters for Impact Strength when the nickel powder was added in flux, in different concentrations. After complete study it was conclusion that we can conclude that the flux and voltage is significantly affects the Impact strength. Travel speed is insignificantly affects the Impact strength. The conformation test also provides the satisfactory result.

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